# Emerging Contaminants in Dairy Farming: Source Characterization and Shallow Groundwater Impacs

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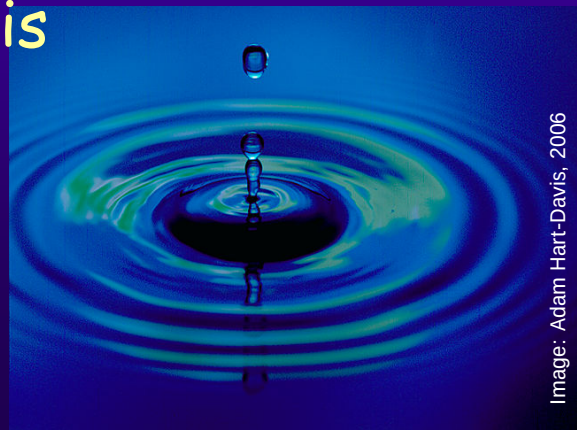

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# Outline

- Overview of dairy farms
- Quantitative estimate of chemicals used in dairy farms
  - -> list of what are potentially present in manure
- Environmental fate and transport in dairies: preliminary results

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# Why dairy?

- Use of pharmaceuticals and hormones is limited in dairy cows.
  - Steroid hormones are not used.
  - Antibiotics are not used while lactating.

  (an exception: monensin, approved as a feed additive)

- The dairy industry in California is a major livestock operation with nearly 2 million lactating cows.

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# Overview of dairy farms

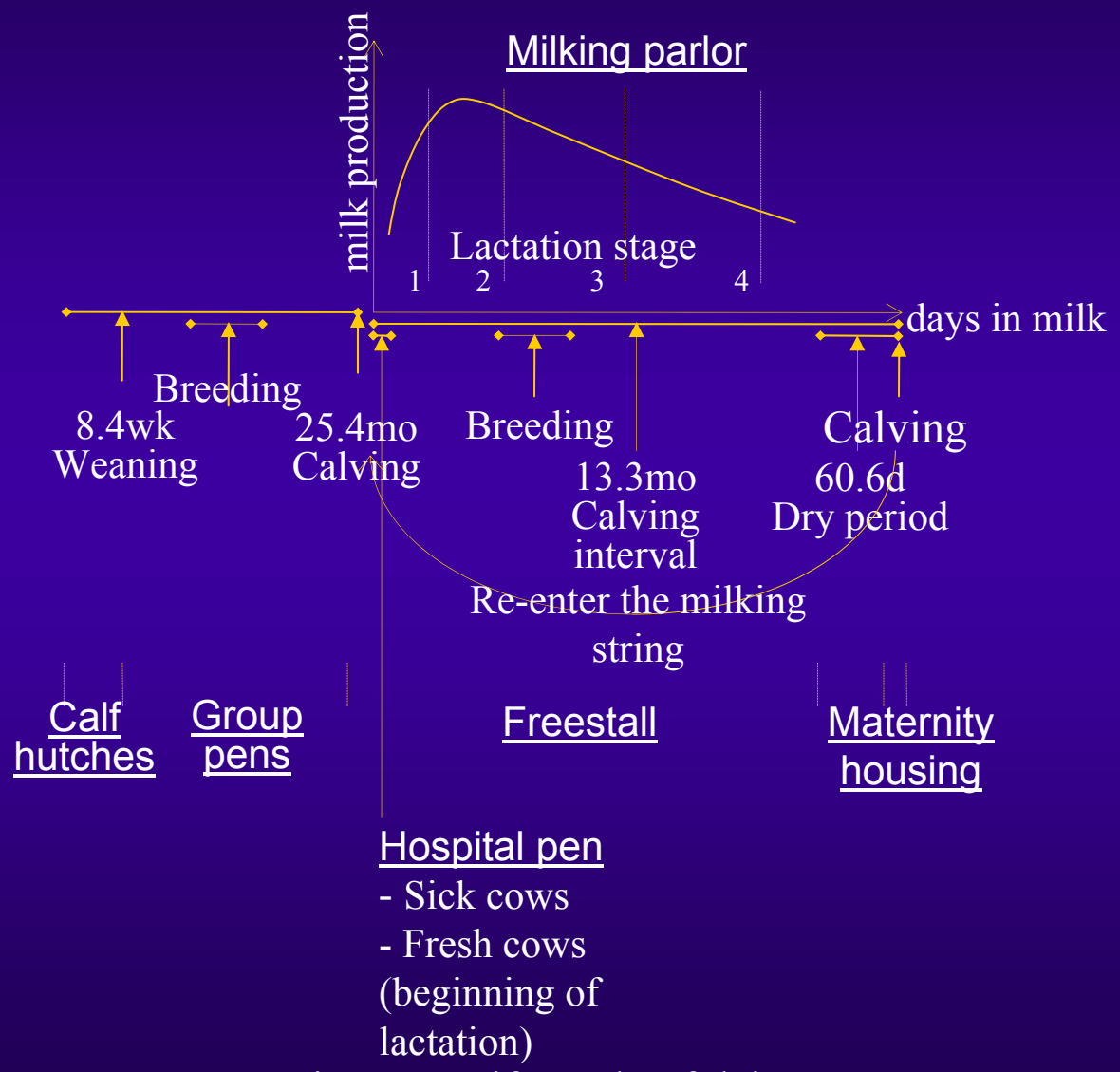


Figure 1. Life cycle of dairy cows

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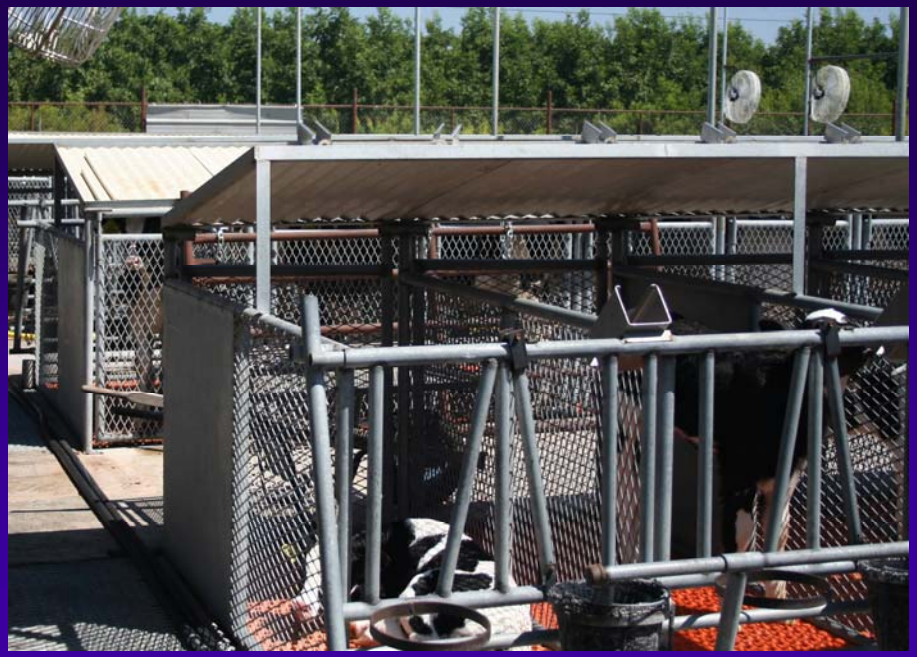

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# Types of chemicals used in dairy management units

| Management unit \ Types of chemicals | Antibiotics - treatment | Antibiotics -prevention | Antibiotics - increase production | Hormones - reproduction | Hormones - Increased production | Disinfectant | Milking machine detergent | Footbath | Insecticide |
|---|---|---|---|---|---|---|---|---|---|
| Calf hutches | X | X | | | | | | | |
| Group pens (heifers) | X | X | | X | | | | | |
| Corrals (lactating cows) | | | X | X | X | | | | |
| Corrals (dry cows) | X | X | | | | | | | |
| Milking Parlor | | | | | | X | X | X | |
| Hospital pen | X | | | | | | | | |
| Premise | | | | | | | | | X |

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# 1. Quantitative Estimates of Use

## 1) Method

- Unit: per lactating cow per day
  = 1 lactating cow + 0.08 unweaned heifer + 0.92 weaned heifer + 0.18 dry cow

- Estimate

| **Typical doses** | | **Usage** |
|---|---|---|
| For different diseases/disorders, preventive purposes<br>Based on e.g. compendium of veterinary product. | x | Numbers of cows affected and treated for different diseases/disorders<br>Based on e.g. USDA survey |

- Case studies

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# 2) Results
# a) Antibiotic use – estimate (1) Purposes

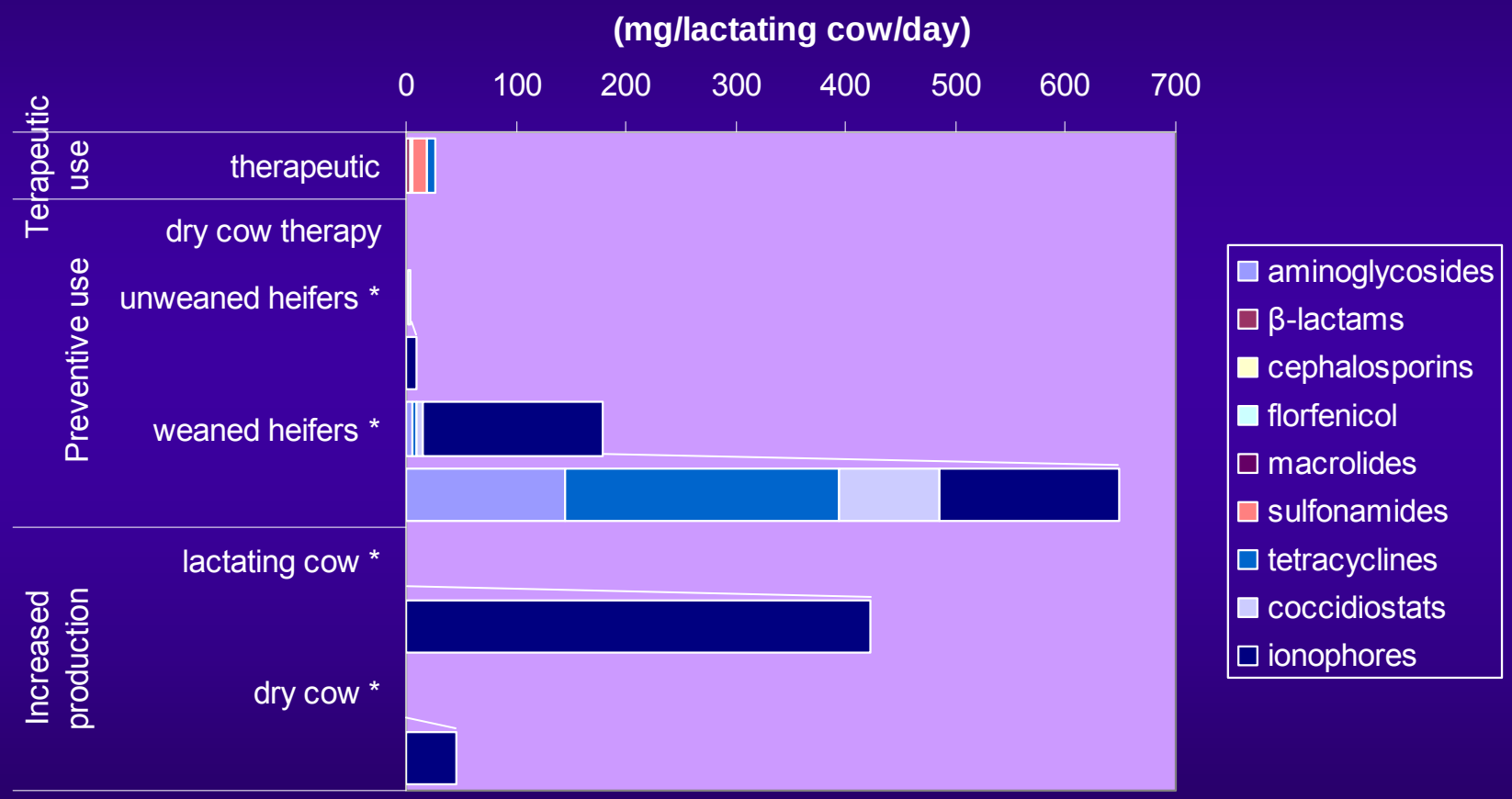


Figure 2. Estimated amount of antibiotics used at dairy farms

*: Shown as ranges that depend on the frequency of antibiotics use and/or the ratio of cows that are given antibiotics.

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# a) Antibiotic use – estimate
# (2) By primary classes

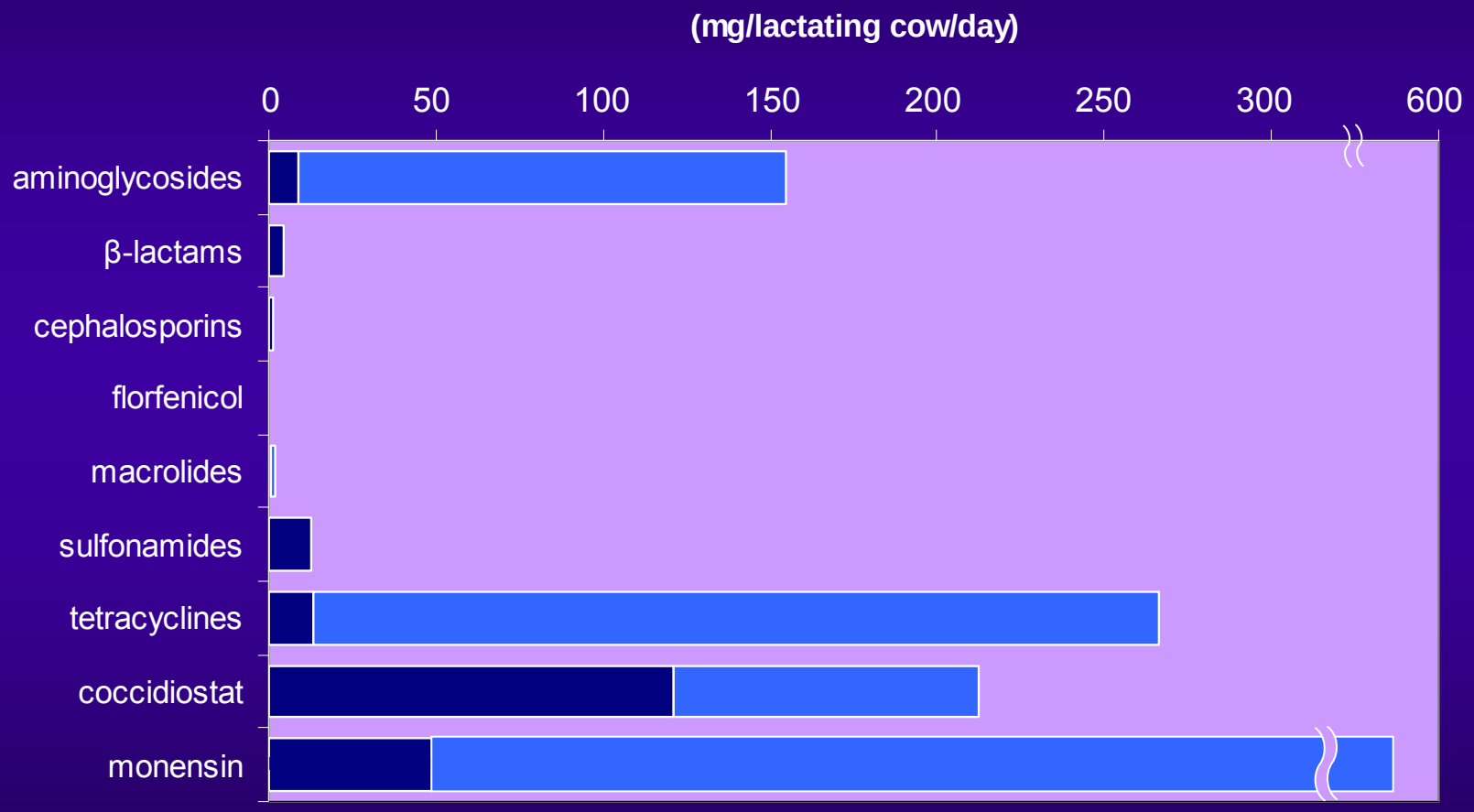


Figure 3. Estimated amount by primary classes of antibiotics

Light blue shows the maximum amount i.e. if used on all the heifers and cows every day.

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# b) Antibiotic use – case studies

| Primary classes | Compound | Amount used (/lactating cow/day) Dairy A | | Dairy B | | prescription (n=13) | |
|---|---|---|---|---|---|---|---|
| aminoglycosides | streptomycin | 11.8 | mg | - | | 3.4 (4.1) | mg (P) |
| | spectinomycin | - | | - | | 0.03 (0.1) | mg |
| | gentamicin | - | | - | | 0.06 (0.2) | mg |
| β-lactams | penicillin G | 455.2 | mg | 41.9 | mg | 3.4 (4.1) | mg |
| | cloxacillin | 88.7 | mg | - | | 0.4 (0.8) | mg (P) |
| | amoxicillin | 36.9 | mg | - | | 0.05 (0.2) | mg (P) |
| | ampicillin | - | | 23.4 | mg | 0.2 (0.6) | mg (P) |
| | hetacillin | - | | - | | 0.02 (0.06) | mg (P) |
| cephalosporins | cephapirin | 88.7 | µg | - | | - | |
| | ceftiofur | 10.1 | µg | 8.1 | mg | 3.5 (4.8) | mg (P) |
| florfenicol | florfenicol | 1.7 | µg | 1.4 | mg | 1.1 (1.9) | mg |
| lincosaminide | pirlimycin | - | | 22.2 | µg | 0.1 (0.2) | mg (P) |
| macrolide | tilmicosin | - | | - | | 0.03 (0.07) | mg |
| | tulathromycin | - | | - | | 0.2 (0.7) | mg |
| sulfonamides | sulfadimethoxine | 16.7 | mg | - | | - | |
| | sulfamethazine | 6.1 | mg | 23.4 | mg | - | |
| | sulfamethoxazole | 6.0 | mg | - | | 3.5 (7.8) | mg |
| tetracyclines | oxytetracycline | 4.9 | mg | 1.9 | mg | 0.02 (0.08) | mg |
| other | trimethoprim | 1.2 | mg | - | | 0.7 (1.6) | mg |
| coccidiostats | decoquinate | - | mg | 5.4 | mg | * | |
| | lasalocid | 2.8 | mg | - | | * | |
| | monensin | 268.1 | mg | 23.1 | mg | * | |

- : not used; * : not available; numbers in parenthesis: standard deviation; (P): prescription

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# c) Hormone use – case studies

| Type | Compound | Amount used (/lactating cow/day) | | |
|---|---|---|---|---|
| | | Dairy A | Dairy B | prescription (n = 15) |
| Growth | sometribove zinc | 22 mg | 14 mg | * |
| Reproductive | oxytocin | 0.5 µg | 0.9 µg | 0.5 (0.6) µg |
| | dinoprost | 340 µg | 207 µg | 90.4 (54.0) µg |
| | gonadorelin | 0.2 µg | 0.5 µg | 0.3 (0.3) µg |
| Anti-inflammatory | isoflupredone acetate | 12 µg | - | 1.6 (2.9) µg |
| | dexamethasone | 68 µg | 181 µg | 20.1 (23.2) µg |
| Natural excretion (estimate) | estrogens | 4.2 mg | | |
| | gestagens | 19.5 mg | | |

*: not available ; numbers in parenthesis: standard deviation

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# d) Other chemicals

- Disinfectant
  - Typically iodine with solubilizing agent.
    0.1~2 g/lactating cow/day
- Milking machine detergent
  - Acid (phosphoric acid, citric acid, sulfuric acid, etc.)
  - Chlorinated alkaline (potassium hydroxide, sodium hypochlorite)
  - Surfactant
- Footbath
  - Copper or zinc sulfate
    2~50 g/lactating cow/day depending on the frequency of use
- Insecticides
  - Fly control (dichlorvos, pyrethrins, etc.)

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# 2. Environmental Fate and Transport

- Study sites
  - 2 dairy farms in the Central Valley, CA
  - ~ 1,400 lactating cows.
- Samples
  - Groundwater (shallow alluvial aquifer)
  - Wastewater (lagoon, flush lane)
  - Surface soil
  - (Soil cores)
- Analytes
  - (DOC, TKN, $NO_3$-N, $NH_4$-N, etc.)
  - $Cu^{2+}$, $Zn^{2+}$, $I^-$
  - Pharmaceuticals
  - Pathogens

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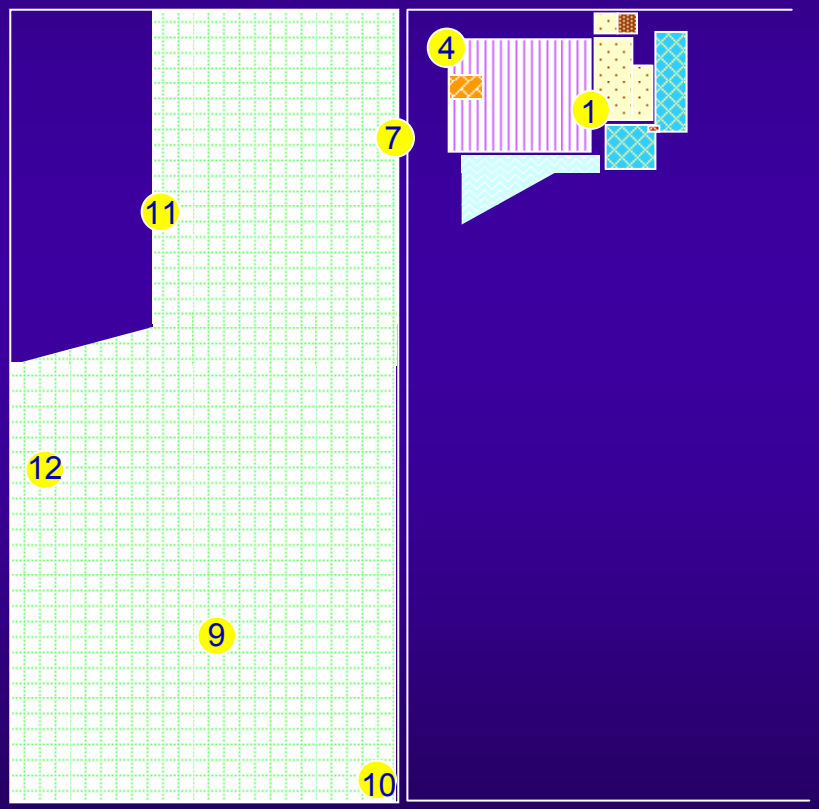
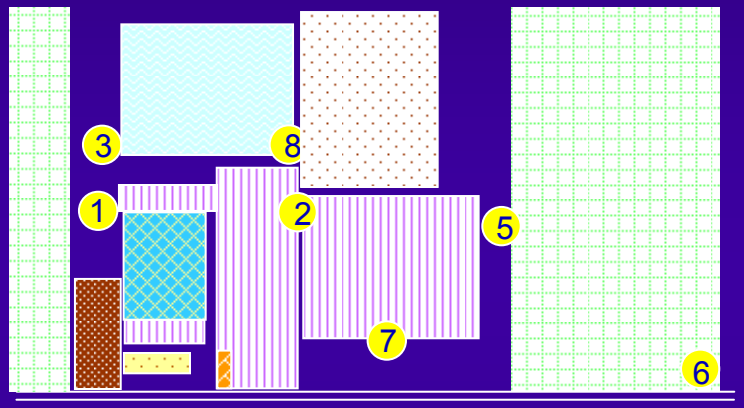
# Layout of the dairy farms

Dairy I




Dairy II




- Milking barn
- Freestall
- Calf hutches
- Heifer freestall
- Feed and equipment storage
- Lagoon
- Field
- Field (manure applied)
- Sampling well

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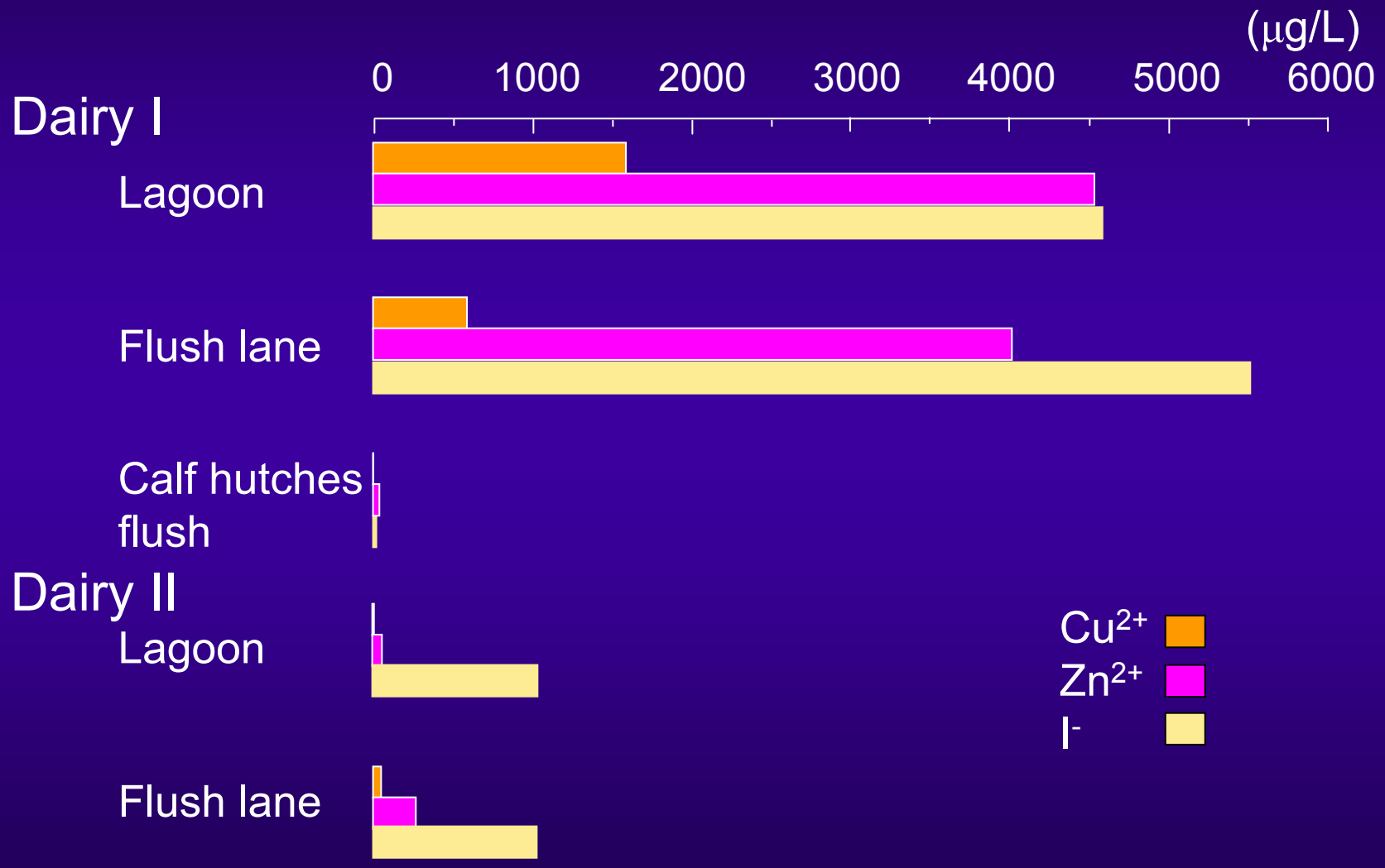
# Results (Oct, 06 sampling)

## 1) Wastewater $Cu^{2+}$, $Zn^{2+}$, $I^-$

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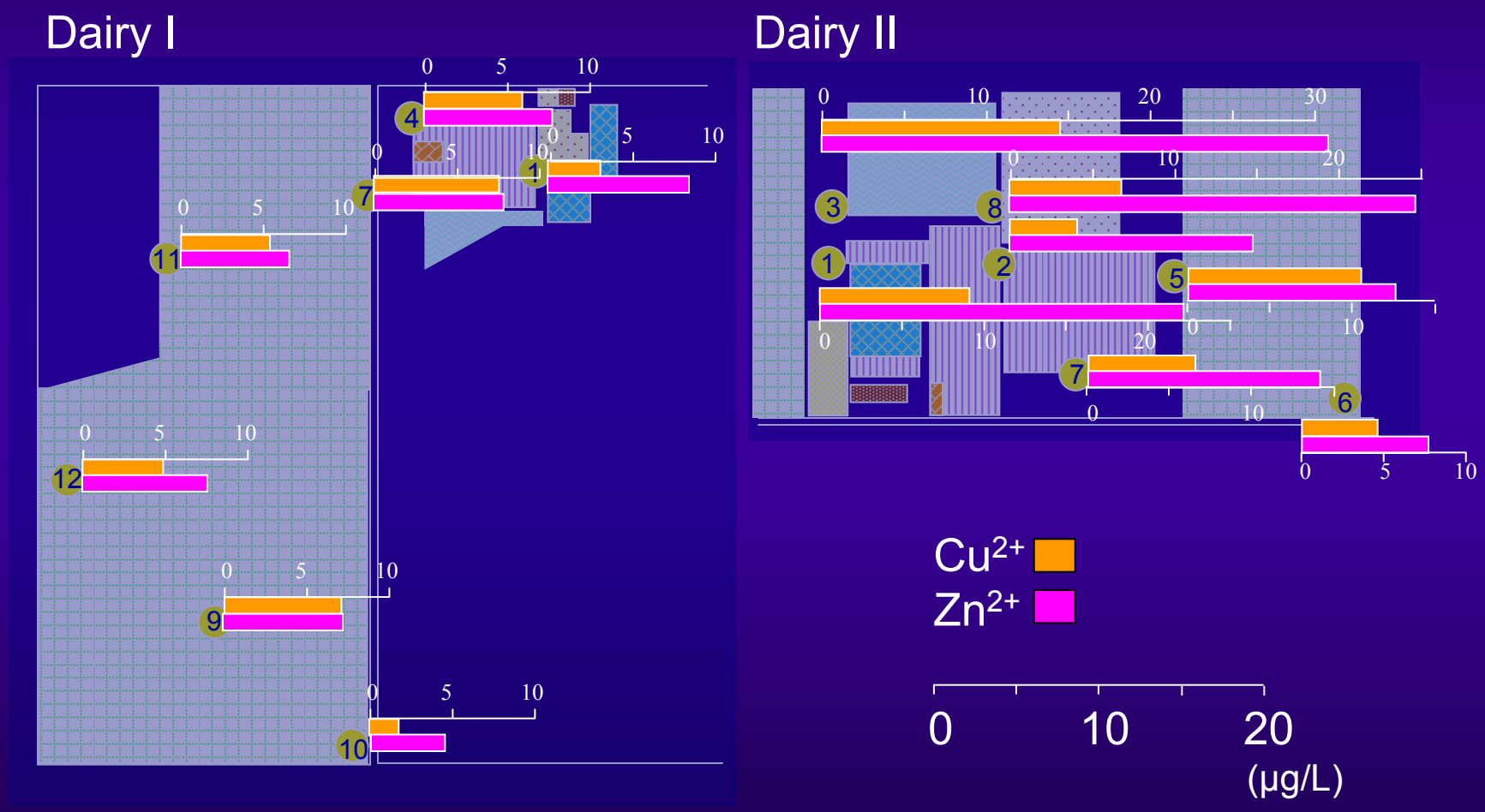
# 2) Groundwater $Cu^{2+}$, $Zn^{2+}$

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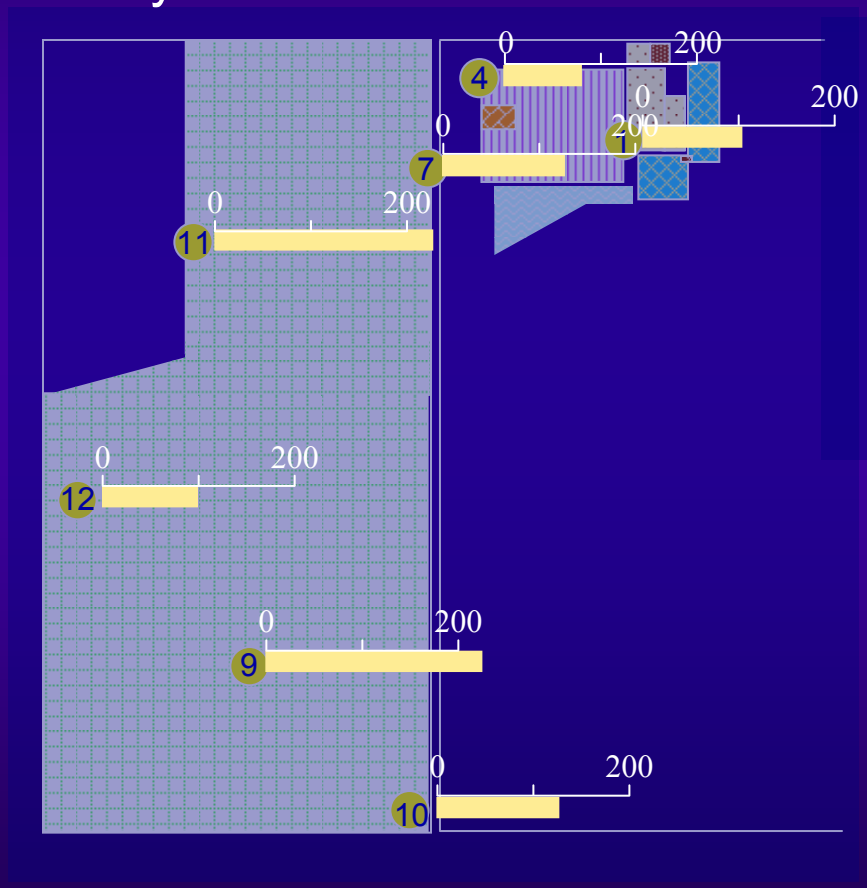
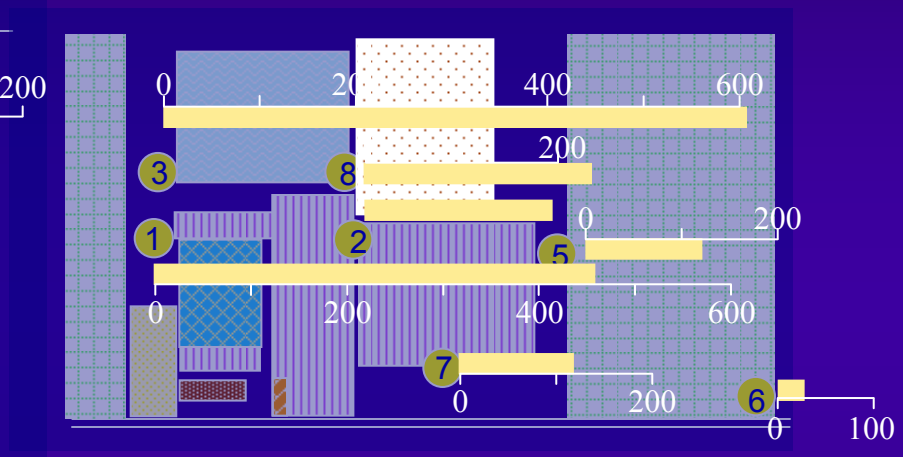
# 3) Groundwater $I^-$

Dairy I




Dairy II




$I^-$

0 200

(µg/L)

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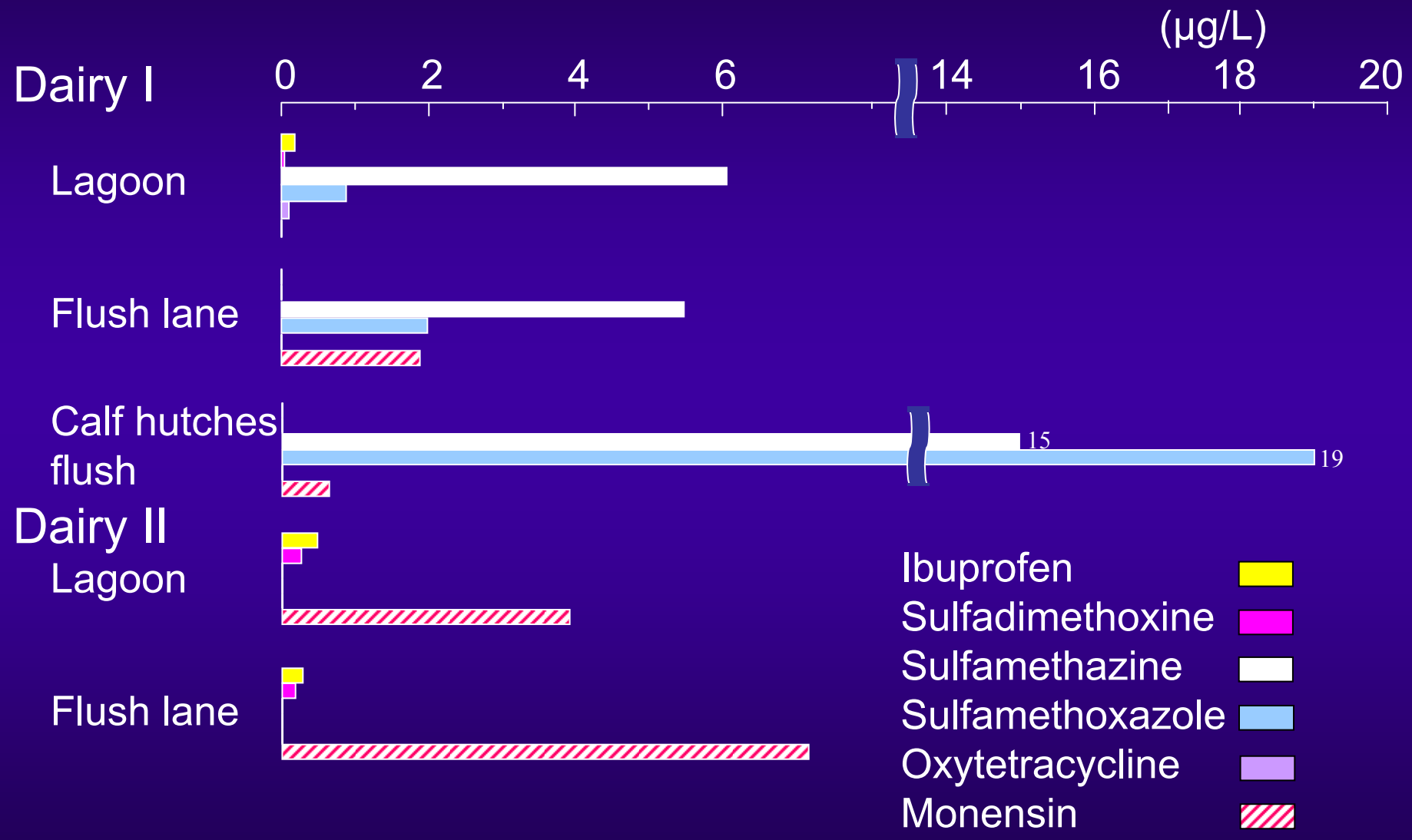
# 4) Wastewater Pharmaceuticals

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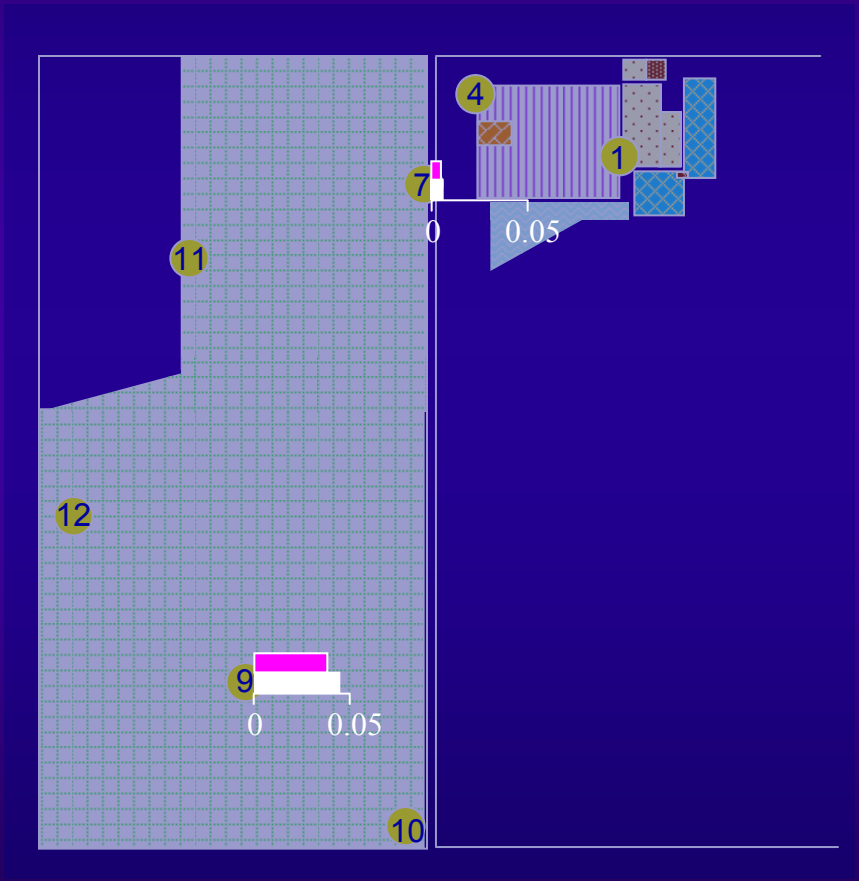
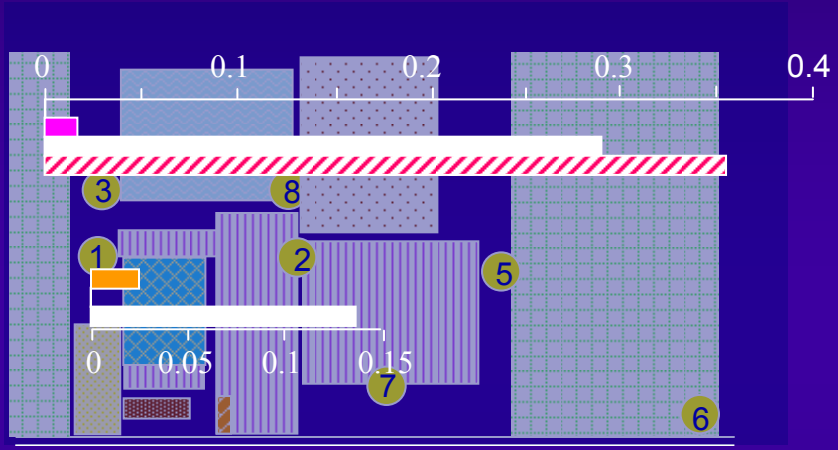
# 5) Groundwater Pharmaceuticals

Dairy I




Dairy II




Tylosin
Sulfadimethoxine
Sulfamethazine
Monensin

0 0.1
(μg/L)

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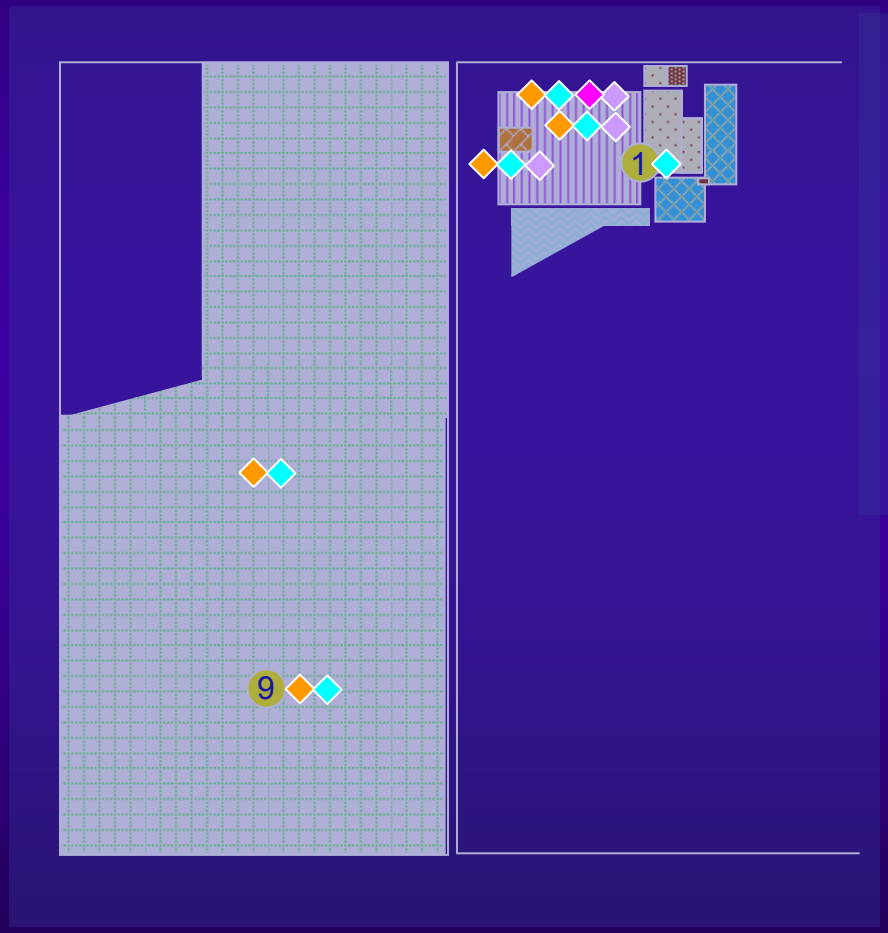
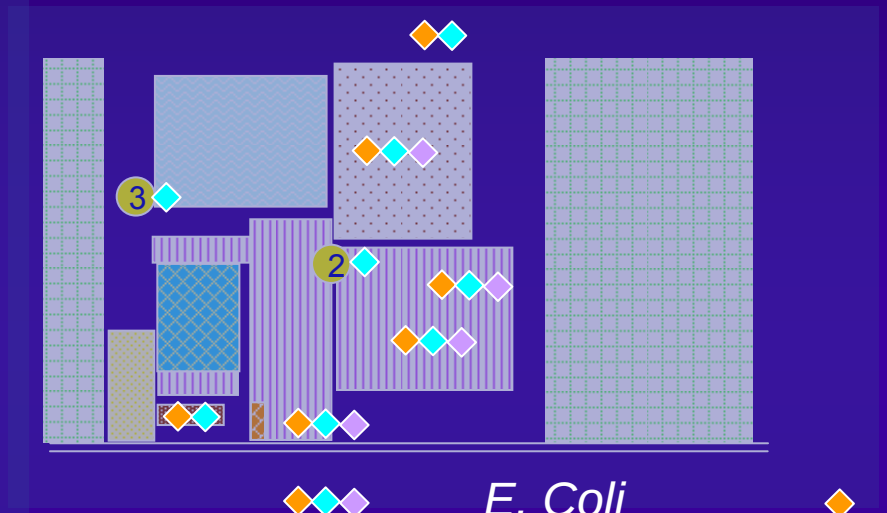
# 3) Indicator bacteria/pathogens detections

## Wastewater, groundwater, surface solids

Dairy I




Dairy II




*E. Coli*
*Enterococcus*
*Campylobacter*
*Salmonella*

Wastewater

| | | |
|---|---|---|
| Dairy I | Lagoon | |
| | Flush lane | |
| | Calf hutches flush | |
| Dairy II | Lagoon | |
| | Flush lane | |

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# Conclusions (1)

- Antibiotic use varies from dairy to dairy.
  - -> larger scale: sales statistics etc.
  - -> smaller scale: interview with dairy owners.
- Feed additive antibiotics used in larger quantities than therapeutic antibiotics.
- Hormones administered are not as siginificant as hormones naturally excreted.
- Other chemicals of concern include copper and/or zinc sulfate, iodine (tracer-indicator), surfactants.

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# Conclusions (2)

- Wastewater
  - $Cu^{2+}$, $Zn^{2+}$ and $I^-$ detected at ~ low ppm level.
  - Various pharmaceuticals.
  - All of the indicator bacteria and pathogens tested.

- Shallow groundwater
  - Affected by dairy activities.
  - Slightly elevated concentrations of $Cu^{2+}$, $Zn^{2+}$.
  - Elevated concentration of $I^-$: possible tracer/indicator of dairy activities.

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# Conclusions (3)

- Sporadic detection of pharmaceuticals in groundwater at low levels (except near lagoon).
- Indicator bacteria in groundwater, but no pathogens.

- Surface solids
  - Indicator bacteria and pathogens.

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# Conclusions (4)

- Need further research:
  - Confirm detections / repeated sampling
  - Focus here is on <u>shallow-most</u> groundwater => research needed on transport in aquifer
  - Fate and transport properties

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